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INVESTIGATION OF THE THERMAL STABILITY OF THE MICROSURFACE OF ASTRONOMICAL MIRRORS FABRICATED FROM AMg6L ALLOY WITH CHROMIUM AND NICKEL COATINGS

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INVESTIGATION OF THE THERMAL STABILITY OF THE MICROSURFACE OF ASTRONOMICAL MIRRORS FABRICATED FROM AMg6L ALLOY WITH CHROMIUM AND NICKEL COATINGS

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ABSTRACT. Experimental study of the effects of low and high temperatures and differences in the linear expansion coefficient of the aluminum alloy AMg6L and electrolytic chromium or chemical nickel coatings on the microsurface quality of astronomical mirrors fabricated with these materials. Coatings of various thicknesses were tested at -95, +20, +60 and +100°C. Temperature variations have no effect on nickel films, but cracks appear on the surface of chromium coatings thicker than 50 μ.

In order to determine the influence of low and high temperatures, the differences in coefficients of linear expansion of aluminum alloy, electrolytic chromium and chemical nickel on the quality of the microsurfaces of mirrors, we performed a series of tests on polished mirrors made of AMg6L alloy with chromium and nickel coatings of various thicknesses. The tests were performed at temperatures of -95, +20, +60 and +100°C. The high temperature tests (+60 and +100°C) were performed in a laboratory thermostat type III-005. The assigned temperature was automatically maintained using a TK-6 contact thermometer with an accuracy of ±1°. The tests of specimens at low temperatures were performed in a hermetically closed box with solid carbon dioxide CO_2 (dry ice). The specimens were placed between blocks of dry ice. The temperature was measured using a thermometer with a measurement range from +20 down to -100°C. The holding time at +100°C was 6 hours; at +60°C -- 8 hours; at -95°C -- 20 hours. The specimens were heated gradually in the thermostat to the required temperature, beginning at room temperature. Cooling to room temperature was also performed gradually in the thermostat. Table 1 shows the greatest and least thicknesses of coatings on the specimens tested directly after application (a) and after grinding and polishing (b).

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The quality of the microsurface was tested by visual inspection, as well as by photography using the "Neofot" universal Zeiss microscope at 200 power magnification before and after the tests.

The results of the tests for the chromium coatings made by milk chroming are presented in Table 2.

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[1] Numbers in the margin indicate pagination in the foreign text.

Table 1. COATING THICKNESS IN MICRONS

	Sample numbers				
Coating	1	2	3	4	5
chromium					
(a)	47-40	55-45	85-100	100-120	220-240
(b)	10-15	30-20	30-50	50-80	120-140
nickel					
(a)	30-35	40-45	50-70	65-75	--
(b)	10-15	15-20	35-40	40-50	--

The results of the experiments show that mirrors with chromium layers from 10 to 50 μ thick (after polishing) show no changes in microsurface properties after the cycle of thermal tests outlined above. With a chromium layer thickness from 50 to 120 μ, cracks were formed on the surface of the mirror after heating. Consequently, there is a limiting chromium layer thickness allowable on AMg6L alloy to be used as the reflecting surface of astronomical mirrors. When this limit is exceeded, microfissures appear on the surface of the mirror. The formation of microfissures on the chrome coating can be explained as follows. As we know, internal stresses arise in an electrolytic layer of /69 chromium, reaching high values (3700-6000 kg/cm^2), these stresses being dependent on the mode of application, thickness, type and condition of the substrate. In this case, the mode of application, type and condition of the substrate were identical for all thicknesses. In chromium layers up to 100-120 μ thick, no fissures were noted immediately after application, while, for example, at 220 μ layer thickness, a cobweb of fissures was noted. These fissures were formed in the process of electrolysis when the internal stress exceeded the tensile strength of the chromium layer.

A change in temperature and difference in the coefficient of linear expansion α of the bonded materials influences the magnitude of the residual internal stress of the chromium layer. The greater the difference in α, the greater the internal stress resulting from changes in temperature. We know the great difference in the coefficients of linear expansion of electrolytic chromium and AMg6L alloy: the electrolytic chromium has $\alpha = 6.25 \cdot 10^{-6}$ 1/deg, while AMg6L alloy has $\alpha = 23.8 \cdot 10^{-6}$ 1/deg.

It follows from the results of the experiment that the production of a high quality microsurface on mirrors made of an aluminum-magnesium alloy with chromium coating requires that the chromium layer be no thicker than 85-100 μ.

The results of the tests show that with slight thickness of the chromium (up to 50 μ) the internal stress does not exceed the tensile strength of the chromium layer, so that no cracking of the chromium is observed. However, as the coating thickness is increased (50 μ or more) the temperature gradient causes stresses to develop within the coating which exceed the tensile strength of the electrolytic chromium, leading, in the final analysis, to the appearance of a cobweb of microfissures on the surface of the coating.

The microsurface of chemical nickel applied to the aluminum-magnesium base, both with the highest thicknesses applied, 65-75 μ (40-50 μ after polishing) and with the least thicknesses, 30-35 μ (10-15 μ after polishing) /70 remained unchanged after the temperature was changed from +100°C to -95°C. Consequently, in this temperature interval (-90°-+100°) and thickness range (up to 65-75 μ) it is possible to produce a high quality microsurface on a nickel layer applied chemically.

It should be noted in conclusion that the thermal investigations on the specimens were performed with the cooperation of Senior Engineer G. G. Lavrent'yeva.

Table 2

Temperature	Sample numbers 1	2	3	4	5	Note
+20°C	surface smooth, without fissures	surface smooth, without fissures	surface smooth, without fissures	surface smooth, without fissures	surface covered with cobweb of fissures	thicknesses of coatings on samples shown in Table 1
+60°C	"	"	"	fissures appeared	no new fissures noted	
+100°C	"	"	fissures appeared	no new fissures noted	new fissures noted	
-95°C	"	"	no new fissures noted	no new fissures noted	no new fissures noted	

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